Embedded Self Organizing Systems (Vol 9. No 3. 2022) (pp.48-53)

Embedded Selforganizing Systems

Special Issue Topic: "International Symposium on Computer Science and Educational Technology "

The Impact on Learning Motivation of Spatial Ability Development Learning Model and Interactive Dynamic Tools

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***Abstract* – This paper reports a study on investigating how different instructional approaches with and without interactive dynamic software affected students' learning motivation and their concept formation of ideas within a framework of descriptive geometry. Learning motivation was measured by taking an Intrinsic Motivation Inventory questionnaire from three groups of students and comparing the answers of the three groups: 1 control and 2 experimental groups.**

Keywords – motivation, Descriptive geometry; learning motivation, engineering education, learning approach.

I. Introduction

Technology has become an increasingly important part of students' lives beyond university, and even within the classroom it can also help increase their understanding of complex and abstract concepts [1]. Because of these benefits, lecturers consider technology-based methods that promise good solutions for their current teaching problems and needs and implement some form of technology into their teaching process – but many instructors face difficulties in doing so. Teaching is a complex combination of what lecturers know about the content they teach, how they decide to teach that content, and the tools they use to carry out their plans. Therefore, considering how technology can best be implemented/matched across diverse and specifics of courses is important.

Computer programs provide ideal environments for the highly-structured cueing, attention-getting, visualization, and practice features that information-processing theorists found so essential to learning. Interactive dynamic technology integration strategies based on constructivist models helps build mental models and increase knowledge transfer to students who have trouble understanding complex and/or abstract concepts. Graphic tools provide visual explanations of abstract concepts and support students' manipulation of geometric 3D models. Researchers refer to visual and interactive qualities of the internet and multimedia resources that draw and hold students' attention [1]. Interactive dynamic tools provide roles like investigating constant relations in the structure of an instructional environment, changing variables to fit newly formed situations, making deductions based on experiences, converting provided verbal and visual information into each other, interpreting the shapes, using visuality and making assumptions [2]. Most of the relations in geometry courses are obtained by means of visual representations of the objects so visual representations are a must for some students to learn geometry. Visual media provided to students not only does contribute to their geometry achievement but also facilitates active involvement of them [2]. Thus, we designed a learning model of using web-based interactive software in order to generate learners' motivation to learn for the experimental-2 group. GeoGebra software was used in the instruction of the Surface projection, a module in the Descriptive geometry course.

Recent years, ineffective learning students' numbers have been increasing on descriptive geometry courses. Therefore the problem is needed to work on concentrating more on how to get attention and motivate them to their learning. For example, in the last eight years at the Mongolian University of Science and Technology (MUST), about over 50% of students learned unsuccessfully on the course [3]. Descriptive geometry is a fundamental principle of engineering and architecture, since it provides students with an intellectual capacity for spatial visualization. When properly taught, Descriptive geometry develops the ability to imagine objects or designs in space and is not just concerned with the reading and interpretation of drawings. Without the ability to think in three dimensions and apply this to drawing, creativity and intelligence when designing new things are not feasible. Well-developed spatial visualization abilities are important conditions for all engineering studies [4]. Students often have difficulty understanding abstract concepts in descriptive geometry. We predicted that the problem might be caused by students' low spatial ability and static learning materials aren't attractive to our students.

Spatial ability is a major factor in human intellect. The ability to visualize objects and situations in one's mind, and to manipulate those images, is a cognitive skill vital to many career fields. Many studies have indicated the importance of spatial ability to the success of engineering students [5], [6]. Still now, there is not any clear agreement on the subskills that this component is made up of. According to Lohman, spatial abilities are divided into spatial visualization, spatial orientation, and spatial relation [7] and these abilities help to understand graphical disciplines and especially descriptive geometry. Spatial visualization skills refer to the ability to encode and maintain spatial information in working memory while transforming it, which are valuable for several STEM fields. For example, the ability to mentally represent sectional views of objects is correlated with one's capacity for spatial visualization [8], [9]. Spatial ability is one dimension of individual difference that can influence a learner's ability to extract information from dynamic, interactive animations [10].

II. Research Objective

The purpose of our study was to investigate how different instructional methods with/without interactive dynamic software affected students' learning motivation. Considering this goal, we developed different learning approaches and measured its impact on students' learning motivation from three groups as Conventional (traditional method), Experimental 1 (traditional plus using interactive dynamic tools) and Experimental 2 (improvement of students' spatial ability). Thus, the following research question is addressed:

1. Is there a significant difference between learning motivation for the conventional, experimental-1 and experimental-2 group students?

III. Methodology

Quasi-experimental study was used in the research experiment. A total of 3 groups were taught the "Surface projection" module of Descriptive geometry and 90 minutes of experiment a week. This experiment uses the Intrinsic Motivation Inventory (IMI) as a measure of learning motivation after each groups' training. So, in the present study, this experimental design was utilized to examine the impact of spatial ability improvement learning model and interactive dynamic GeoGebra[1] software on the increase of students' learning motivation (Fig. 1).

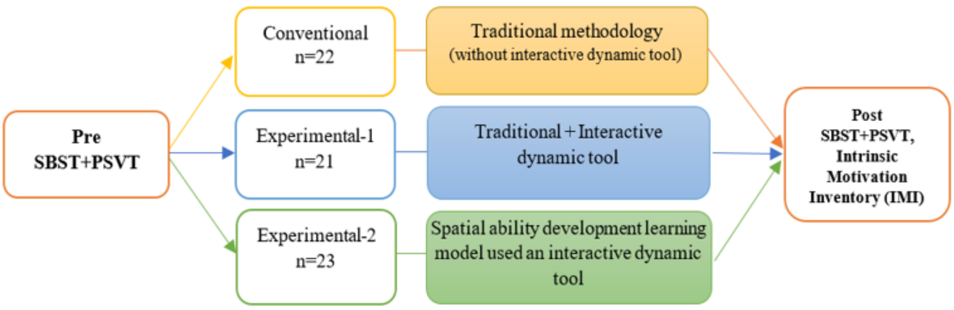

Fig. 1. Experimental design

A. Participants

A total of 110 students who studied the Descriptive Geometry course at Mongolian University of Science and Technology participated in this study. However, we removed 44 students whose participants did not fully complete all instruments and not freshmen. Thus, only 66 participants from 3 groups (22 conventional, 21 experimental 1, and 23 experimental 2) were taken into consideration in the analysis.

B. Material

Learning motivation: The Intrinsic Motivation Inventory is a multi-dimensional measurement questionnaire intended to assess participants' subjective experience related to target activity in laboratory experiments. There is a standard 22-item version that has been used in several studies, with four subscales. These scales are interest/enjoyment, perceived competence, perceived choice, and pressure/tension. A total of 66 students responded to a 7-point Likert scale ranging from strongly agree (7) agree (6) somewhat agree (5) neutral (4) somewhat disagree (3) disagree (2) strongly disagree (1).

C. Procedure

The experiment was conducted between 9-15 weeks of the fall semester in the academic year of 2021-2022. At the end of the experiment, an intrinsic motivation inventory questionnaire was obtained to explore learners' learning motivations, interests, and collaborations and the students were administered the electronic version of IMI within MS Office 365 Form.

D. Learning design

The teaching method of the conventional group is the traditional method. Conventional and experimental-1 groups have similar teaching methods and lesson plans, but different learning tools whereas experimental-2 group's teaching method is tailored based on a three steps learning model for students' spatial ability development. Figure 2 below illustrates the learning condition model of the three groups.

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[1] GeoGebra (the name is made from the two words Geometry and Algebra) is an interactive geometry, algebra, statistics and calculus application, intended for learning and teaching mathematics and science from primary school to university level. GeoGebra is available on multiple platforms, with apps for desktops (Windows, macOS and Linux), tablets (Android, iPad and Windows) and Web. www.wikipedia.com

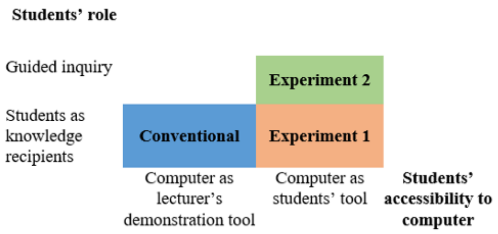


Fig. 2. Model of learning environments in the three groups

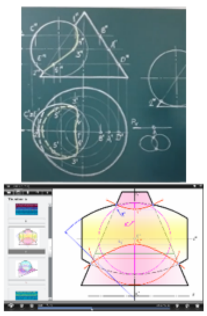
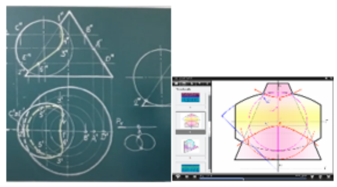
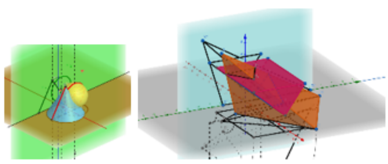
The comparison of learning activities for these three groups is shown in Table I. The training steps and activities of the conventional and experimental-1 groups are similar, but the tools used are different (Table I1). Also, the conventional group used traditional teaching methods and animation learning material that is created using Adobe Flash software to teach students the descriptive geometry.

TABLE I. COMPARISON BETWEEN THREE GROUPS IN TERM OF THE ACTIVITIES AND TIME

Groups	**Conventional** (n=22)	**Experimental 1** (with interactive dynamic tools) (n=21)	**Experimental 2** (through 3 step learning model) (n=23)
Pre-training	SBST+PSVT		
Topic	Surface projection		
Duration	90 min in per week		
Learning process	Review (10 min) Explanation of lecturer (20 min) Work independently (35 min) Check answer (15 min) Q&A (10 min)	Review (10 min) Explanation of lecturer (20 min) Work independently (35 min) Check answer (15 min) Q&A (10 min)	Seeing (15 min) Imaging (25 min) Drawing (50 min)
Post training	SBST+PSVT, Learning motivation		

For the experimental-2 group, a learning model that is designed for improvement of spatial ability is tested. In order to systematically organize the learning model into a learning process we provide subskills of spatial ability integrated into the levels of Geometry thinking through an interactive dynamic software named GeoGebra. Accordingly, the focused visual spatial skills consisted of two subskills, specifically mental rotation and mental transformation. Geometric thinking levels are hierarchical, while the spatial skills are not related to each other but have their own criteria representing certain abilities. To ensure that two spatial skills could be applied to the Geometric thinking level, the learning model pursued the guidelines as shown in Figure 3. The activities were arranged systematically into parts of spatial visualization model [11]. It consisted of three parts (seeing, imaging, and drawing) and each one of them contained several types of exercises. This study was conducted for seven weeks in line with the weekly lesson plan set by one of the authors.

TABLE II. COMPARISON OF THE LEARNING ACTIVITIES FOR CONVENTIONAL AND EXPERIMENTAL 1 GROUPS

Learning tools of the conventional group	**Learning steps**	**Learning tools of the experimental 1 group**
Blackboard and animation tools 	**Review** **Explanation of lecturer** **Work independently** **Check answer** **Q&A**	Blackboard and animation tools  Interactive dynamic tools 

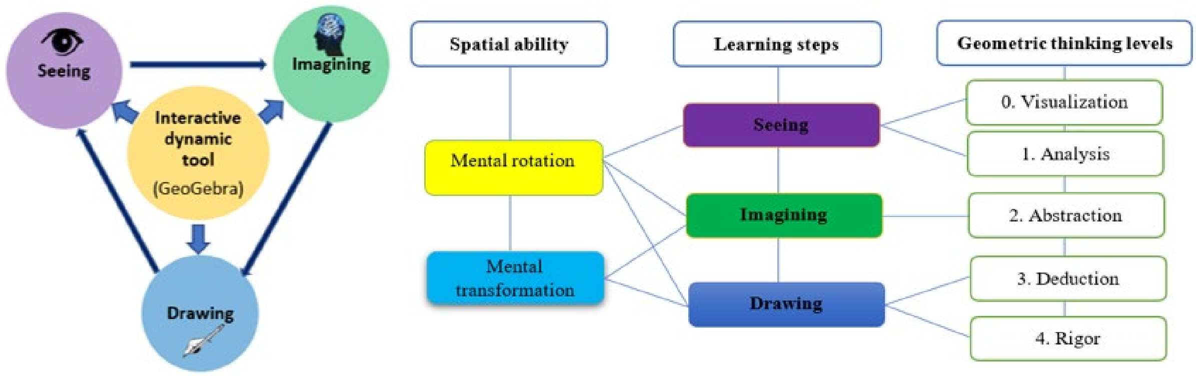


Fig. 3. Relationship diagram among subskills of spatial ability and geometric thinking levels to the learning steps

IV. RESULTS

A. *Internal reliability*

Cronbach's alpha was calculated for each subscale and aggregated to test its reliability. The reliability of the motivation questionnaire was Cronbach's alpha (α=0.88). The Cronbach's alpha of the subscale questions was such as Interest/enjoyment (0.85), Perceived choice (0.47), Perceived competence (0.89), Pressure/tension (0.60).

B. *Results of motivation for three groups*

Table III shows the ANOVA analysis results of the IMI questionnaires of the three groups (experimental 1, experimental 2, and conventional) and three groups of significant difference of subscales. The results showed that there were statistical differences in learning motivation among the three groups, F= 6.33, Sig = 0.003, $p < 0.05$, and as shown in Table III, the differences between the three groups of the Interest/enjoyment subscale are the highest F=10.95, $p<0.05$, and Perceived competence subscale are F=9.94, $p<0.05$. There was no significant difference between the groups $p> 0.05$ for Perceived choice (F=2.49) and Pressure/tension (F=0.08) subscales. The result shows that the students did not feel any pressure or tension during the training and we supposed that perceived choice questionnaires were not fully understood by them.

TABLE III. ANOVA RESULTS OF IMI QUESTIONNAIRE VARIABLE AND THREE GROUPS SIGNIFICANT DIFFERENCE OF SUBSCALES

Groups	Subscales of motivation									Total	
	Interest/enjoyment			Perceived choice		Perceived competence		Pressure/tension			
	N	M	SD	M	SD	M	SD	M	SD	M	SD
Conventional	22	3.75	1.00	4.35	.71	3.51	.93	3.98	.65	4.12	0.67
Experimental 1	21	5.03	.99	4.09	.91	4.89	1.28	4.04	.83	4.81	0.83
Experimental 2	23	4.91	.97	4.73	1.16	4.89	1.28	3.95	.85	4.89	0.86
F	10.95			2.49		9.94		0.08		6.33	
p	**0.000**			0.091		**0.000**		0.926		**0.003**	

The Tukey Post-hoc test was used to estimate whether there was a significant difference between the mean of the experiment groups. The results of this analysis are shown in Table IV. As can be seen from the result, there was no significant difference ($p> 0.05$) between the learning motivation of the experimental-1 and the experimental-2 groups. For these two groups, the interactive dynamic learning tools were applied and the learning methods used were different. It also shows that there was a significant difference between the mean of the conventional and the experimental-1 group at $p <0.05$. For these two groups, the learning tools were different and the learning methods used were the same. There were significant differences in learning motivation between the conventional and the experimental-2 group, as shown by $p<0.05$. The learning tools for these two groups were different and the learning model used was different as well.

TABLE IV. THE MULTIPLE COMPARISONS OF THREE GROUPS AND THREE GROUPS SIGNIFICANT DIFFERENCE OF SUBSCALES

Groups		Subscales of motivation				
		Interest/enjoyment	Perceived choice	Perceived competence	Pressure/tension	Total
		p				
Conventional	**Experimental 1**	**.000**	.647	**.001**	.960	**.016**
	Experimental 2	**.001**	.387	**.001**	.994	**.005**
Experimental 1	**Conventional**	**.000**	.647	**.001**	.960	**.016**
	Experimental 2	.915	.077	1.000	.923	.933
Experimental 2	**Conventional**	**.001**	.387	**.001**	.994	**.005**
	Experimental 1	.915	.077	1.000	.923	.933

C. Correlation results of IMI

It can be seen from the comparison between the mean values of the three groups. Then calculate the Pearson correlation coefficient to measure the linear relationship between the two variables of IMI (interest/enjoyment, perceived/competence, perceived choice and pressure/tension). Table V shows the results. The results of the analysis of the correlation between the other subscales of interest/enjoyment. High positive degree of correlation appears between interest/enjoyment and perceived competence (r = .852**). Negligible degree of correlation appears between interest/enjoyment and perceived choice (r= .281*), between interest/enjoyment and pressure/tension there was not statistically significant correlation (r = .231).

The results of the analysis of the correlation between the other subscales of perceived competence. Low degree of correlation appears between perceived competence and perceived choice (r = .246*), between perceived/competence and pressure/tension was not statistically significant correlation (r = .127). The results of the analysis of the correlation between the other subscales of perceived choice. Middle degree of correlation appears between perceived choice and pressure/tension (r = .416**).

TABLE V. CORRELATION BETWEEN SUBSCALES OF LEARNING MOTIVATION

Subscales of motivation	relation	Subscales of motivation			
		Interest/enjoyment	Perceived choice	Perceived competence	Pressure/tension
Interest/enjoyment	r	1	**.281***	**.852****	.231
	p		.022	.000	.061
Perceived choice	r		1	**.246***	**.416****
	p			.046	.001
Perceived competence	r			1	.127
	p				.310
Pressure/tension	r				1
	p				

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

V. DISCUSSION AND CONCLUSION

According to the outputs, for the 2 groups that used interactive dynamic tools, the agreement level of the Interest/enjoyment was higher than the conventional group, so it can be considered that the interactive dynamic tools supported them in completing the task successfully and were interesting.

Result of perceived choice was not significant between the three groups. It was seen that there was no difference between the groups in terms of teaching methods and tools that led them to perform the tasks.

It is believed that the students' satisfaction with the performance of the task and their confidence in their abilities are higher in the 2 groups that used interactive dynamic tools than in the traditional group.

Feeling under pressure was somewhat agreeable for the 3 groups, with doubts about whether they could think through tasks, not being able to finish on time. Although it used interactive dynamic tools, it was somewhat annoying.

The use of interactive dynamic materials in teaching has a positive effect on students' enjoyment of learning and sense of competence compared to traditional learning methods. On the other hand, it was observed that the students were at the same level whether it was optional for them to perform the task and whether they were under pressure.

According to the results of our research, the learning motivation indicator of the group supported by the development of students' spatial visualization abilities with interactive dynamic materials was slightly higher than that of the group that combined traditional training with interactive dynamic materials, and no statistical difference was observed. Also, the students who studied using traditional methods had less motivation to learn compared to the training groups for the development of students' spatial visualization abilities based on interactive dynamic tools and traditional methods supported by interactive dynamic tools, and this leads to the conclusion that the introduction of interactive dynamic tools into the training has a positive effect on the student's learning motivation.

Based on this, for both groups, it is clear that learning activities with interactive dynamic tools have positive effects on the students' learning motivation.

We can show that the interactive dynamic learning environment impacts effectively both of the experimental 2 groups students' learning motivation compared to conventional group. The significant positive effect of the interactive dynamic learning environment on the performance outcome has provided empirical evidence of the potential of dynamic GeoGebra software to support and enhance learning motivation of students in Descriptive Geometry.

VI. LIMITATION AND FUTURE DIRECTION

The limitation of this research study only measured learning motivation for the three groups and the results of spatial ability improvement learning model will be considered in future research.

VII. ACKNOWLEDGEMENTS

The authors acknowledge the support of students who participated in this study.

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